Aerosol invigoration and restructuring of Atlantic convective clouds

Ilan Koren,[1,2] Yoram J. Kaufman,[1] Daniel Rosenfeld,[3] Lorraine A. Remer,[1] and Yinon Rudich[4]

Received 8 April 2005; revised 10 June 2005; accepted 6 July 2005; published 30 July 2005.

[1] Clouds and precipitation play crucial roles in the Earth's energy balance, global atmospheric circulation and the availability of fresh water. Aerosols may modify cloud properties and precipitation formation by modifying the concentration and size of cloud droplets, and consequently the strength of cloud convection, and height of glaciation levels thus affecting precipitation patterns. Here we evaluate the aerosol effect on clouds, using large statistics of daily satellite data over the North Atlantic Ocean. We found a strong correlation between the presence of aerosols and the structural properties of convective clouds. These correlations suggest systematic invigoration of convective clouds by pollution, desert dust and biomass burning aerosols. On average increase in the aerosol concentration from a baseline to the average values is associated with a 0.05 ± 0.01 increase in the cloud fraction and a 40 ± 5mb decrease in the cloud top pressure. **Citation:** Koren, I., Y. J. Kaufman, D. Rosenfeld, L. A. Remer, and Y. Rudich (2005), Aerosol invigoration and restructuring of Atlantic convective clouds, *Geophys. Res. Lett.*, *32*, L14828, doi:10.1029/2005GL023187.

1. Introduction

[2] Based on a few case studies, it has been suggested [*Andreae et al.*, 2004; *Williams et al.*, 2002] that the suppression of warm rain by aerosol causes most of the condensates to ascend, freeze and release the latent heat of freezing before precipitating. Delayed precipitation leads to more persistent updrafts and to more vigorous clouds before the precipitation-induced downdrafts take over. In addition, smaller droplets freeze at higher altitudes and at lower temperatures [*Rosenfeld and Woodley*, 2000]; therefore more latent heat is released higher in the atmosphere. The magnitude and robustness of these aerosol effects have not yet been investigated in a variety of meteorological conditions.

[3] Here we report strong correlations between aerosol loading and convective cloud properties. We see the correlations in all scales, from droplet scale to the extent and shape of the entire cloud. We show using large statistics that an increase in aerosol concentration correlates with changes in the cover, height and anvil portion of convective clouds. We show these correlations occur repeatedly in three latitude belts of the Atlantic Ocean each with its own unique cloud dynamics and aerosol type.

[1]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[2]JCET, University of Maryland, Baltimore County, Baltimore, Maryland, USA.
[3]Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, Israel.
[4]Department of Environmental Sciences, Weizmann Institute, Rehovot, Israel.

0094-8276/05/2005GL023187$05.00

2. Analysis

[4] We use three months (June-August 2002) of MODIS (MODerate resolution Imaging Spectroradiometer) [*Salomonson et al.*, 1989] Level 3 data from the Terra satellite over the northern Atlantic Ocean from 60°N to the Equator (covering ~4 billion km2). The satellite products include cloud fraction, optical thickness and droplet effective radius, each further partitioned by thermodynamic phase (ice/water), cloud top pressure and temperature [*King et al.*, 2003; *Platnick et al.*, 2003] and also by aerosol optical depth (AOD) at 550 nm [*Tanré et al.*, 1997; *Kaufman et al.*, 1997; *Remer et al.*, 2005]. MODIS measures daily cloud and aerosol reflection of sunlight with resolution of 0.25–1 km. The daily data are averaged into a 1-degree grid (MODIS algorithms, Level 3, available at http://modis-atmos.gsfc.nasa.gov/DAILY/atbd.html), that includes information on clouds and the surrounding aerosols (unless the grid box is completely overcast). We also used NCEP (National Center for Environmental Prediction) reanalysis [*Kalnay et al.*, 1996] and MODIS precipitable water vapor as a measure of the meteorology.

[5] In this study we focus on correlations between aerosols and the properties of deep convective and high cloud fields. Clouds were classified based on their top pressure, thermodynamic phase and cloud spatial homogeneity. Convective clouds are identified based on the variation in cloud top pressure among adjacent grid boxes and based on the optical depth of ice and water. The cloud classification algorithm was tuned on manually classified clouds followed by manual verification process of randomly selected cases. During the northern hemisphere summer, the average cloud fraction in the studied area is ~0.6, of which 75% are classified as deep convective and high clouds and 25% as marine stratocumulus and shallow cumulus (analyzed in a different study [*Kaufman et al.*, 2005]).

[6] We performed the analysis of the convective clouds separately for three regions characterized by different synoptic conditions: 0–15°N, including the ITCZ (Intertropical Convergence Zone), where the prevailing wind is easterly and carries mainly dust aerosol from the Sahara to the tropics of America; 16N–45N (sub tropical zone), where most of the deep convection develops in the southerlies along the Americas, transporting aerosols from the tropics to the mid-latitudes; and 46N–60N, where the system is dominated by the westerly wind that brings pollution aerosol from North America to Europe (mid-latitudes). In the tropical and mid-latitude zones the average flow is zonal (east-west) and the convective clouds are distributed